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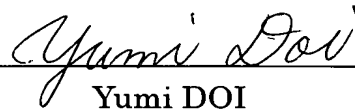
PAINT FOR FORMING INSULATING FILM, AND PLASMA DISPLAY  
PANEL USING THE PAINT AND METHOD OF MANUFACTURING THE  
SAME

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translator of the documents attached and I state that the following is a true  
translation to the best of my knowledge and belief of Japanese Patent  
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At Osaka, Japan

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Yumi DOI

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This is to certify that the annexed is a true copy of the following application as filed with this Office.

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[Document Name] SPECIFICATION

[TITLE OF THE INVENTION]

PAINT FOR FORMING INSULATING FILM, AND PLASMA DISPLAY  
PANEL USING THE PAINT AND METHOD OF MANUFACTURING THE  
SAME

[CLAIMS]

[Claim 1] A paint for forming an insulating film comprising:  
an inorganic component comprising inorganic fine particles, and  
an organic component comprising at least a resin for binding the  
inorganic fine particles and a solvent in which the resin is dissolved,  
wherein the solvent forms a contact angle of less than 5° with an  
inorganic material.

[Claim 2] The paint for forming an insulating film according to  
claim 1, wherein the inorganic material is at least one selected from glass  
compounds, ceramic compounds, and metal compounds.

[Claim 3] The paint for forming an insulating film according to  
claim 1 or 2, wherein the solvent contains 50 wt. % or more of at least one  
solvent selected from diethyl carbitol and carbitol acetate.

[Claim 4] The paint for forming an insulating film according to any  
one of claims 1 to 3, wherein the paint is used for forming an insulating film  
used in a plasma display panel, a plasma address liquid crystal display, or  
an image forming apparatus using an electron-emitting element.

[Claim 5] A method of manufacturing a back plate of a plasma  
display panel comprising:  
coating the paint for forming an insulating film according to any one  
of claims 1 to 3 onto a back plate of a plasma display panel, the back plate  
being provided with address electrodes, and  
firing the paint to form an address electrode protective film.

[Claim 6] The method according to claim 5, wherein ultraviolet  
cleaning is performed before forming the address electrode protective film.

[Claim 7] A back plate of a plasma display panel having an address  
electrode protective film formed by the method according to claim 5 or 6.

[Claim 8] A method of manufacturing a back plate of a plasma  
display panel comprising:  
coating the paint for forming an insulating film according to any one

of claims 1 to 3 onto a back plate of a plasma display panel, and  
firing the paint to form a partition wall.

[Claim 9] The method according to claim 8, wherein ultraviolet  
cleaning is performed before forming the partition wall.

[Claim 10] A back plate of a plasma display panel having a partition  
wall formed by the method according to claim 8 or 9.

[Claim 11] A method of manufacturing a front plate of a plasma  
display panel comprising:

coating the paint for forming an insulating film according to any one  
of claims 1 to 3 onto a front plate of a plasma display panel, the front plate  
being provided with display electrodes, and  
firing the paint to form a dielectric layer.

[Claim 12] The method according to claim 11, wherein ultraviolet  
cleaning is performed before forming the dielectric layer.

[Claim 13] A front plate of a plasma display panel having a  
dielectric layer formed by the method according to claim 11 or 12.

## [DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical field to which the invention pertains]

The present invention relates to a paint for forming an insulating  
film used in a plasma display panel, a plasma address liquid crystal display,  
or an image forming apparatus using electron-emitting elements, and to a  
plasma display panel in which an address electrode protective film or  
partition walls provided on its back plate and a dielectric layer provided on  
its front plate are formed using this paint.

[0002]

[Prior Art]

As an image forming apparatus that can be substituted for a heavy  
and large conventional cathode-ray tube, there has been increasing demand  
for a thin and light flat-type display or, as it is called, a flat panel display  
(FPD). A typical FPD is a liquid crystal display (LCD). However, LCDs  
have problems such that images obtained are dark, a viewing angle is  
narrow, and it is difficult to increase an area thereof. Therefore, in recent  
years, a plasma display panel (PDP) and an image forming apparatus using

electron-emitting elements are attracting great attention and the demand for them has been growing because they can be increased in definition and in size further than LCD.

[0003] FIG. 1 shows one example of a structural view (cross-sectional view) of PDP. Hereinafter, the principle of display by PDP will be explained with reference to FIG. 1.

[0004]

Between each pair of display electrodes 3 provided on a front glass substrate 1, plasmas are discharged to generate ultraviolet rays. The ultraviolet rays excite phosphors 6, which are separated from each other by partition walls 9 provided on a back glass substrate 2, to make the phosphors emit visible lights. The visible lights emitted from the respective phosphors 6 pass through an MgO film 10, a front dielectric layer 7, and the front glass substrate 1 to be displayed as an image. At this time, by applying signals to selected address electrodes 5 to specify the discharge cells to be displayed, a desired image can be obtained.

[0005]

To generate and maintain plasmas, the electrodes need to be insulated from each other. The front dielectric layer 7 is provided to obtain an insulating effect. The front dielectric layer 7 is obtained as follows: a paint obtained by dispersing a resin and inorganic fine particles, which are glass powder mainly containing Si or the like, in an organic solvent is coated onto the front glass substrate, and the paint is dried and fired, thereby giving the dielectric layer 7. The organic solvent is vaporized during the drying process. During the firing process, the resin is vaporized and the glass powder melt to be joined to each other. The paint turns into a glass film when cooled after the firing, thus forming the front dielectric layer 7.

[0006]

On the back glass substrate 2, the back dielectric layer 8 is provided for the purpose of protecting the address electrodes 5. The back dielectric layer 8 is formed in the same manner as that for the front dielectric layer 7.

[0007]

Typically, an insulating film formed using glass is used as the front dielectric layer 7 and the back dielectric layer 8. For example, JP 2000-16835 A proposes using an insulation paste containing 70 to 95 wt. %

of glass powder having an average particle diameter of 0.3 to 1.5  $\mu\text{m}$  and a maximum particle diameter of not more than 10  $\mu\text{m}$  and 5 to 30 wt. % of an organic component as a paste for forming thin insulating films as protective films provided on a front glass substrate and a back glass substrate and thick insulating films covering the electrodes on both the glass substrates.  
[0008]

As the phosphors 6, phosphors that emit lights of R (red), G (green), and B (blue), respectively, are used, and the partition walls 9 are provided to prevent these three colors from being mixed with each other. Like the front dielectric layer 7 and the back dielectric layer 8, the partition walls 9 are obtained also by coating a paint obtained by dispersing a resin and inorganic fine particles, which are glass powder mainly containing Si or the like, in an organic solvent, drying the paint, and then exposing/developing the paint in a desired pattern (photolithography) or etching the paint in a desired pattern by having fine particles of Zr or the like collide with the paint (sandblasting).  
[0009]

Known electron-emitting elements can be broadly classified into two types: hot cathode electron-emitting elements and cold cathode electron-emitting elements. In recent years, an image forming apparatus using cold cathode electron-emitting elements has been attracting attention because it does not consume power during the standby period and can attain a high current density. The cold cathode electron-emitting elements can be classified into those of field emission type (FE type), metal/insulator/metal type (MIM type), and the like. In an image forming apparatus using cold cathode electron-emitting elements, phosphors emit lights upon being irradiated with electron beams emitted from the electron-emitting elements, thereby displaying an image.  
[0010]

Like the plasma display panel, the image forming apparatus using cold cathode electron-emitting elements also employs a glass insulating film. For example, a back glass substrate of the image forming apparatus includes a plurality of electron-emitting elements and wirings arranged in matrix for connecting these elements. These wirings are arranged in the X direction and Y direction to intersect with each other at the portions of the



electrodes of the electron-emitting elements. To insulate the wirings and the electrodes at these intersections, a belt-shaped insulating film is needed. Such an interlayer insulating film is formed using, for example, glass containing lead oxides as a main component so that the thickness of the film becomes 10 to 100  $\mu\text{m}$ , preferably 20 to 50  $\mu\text{m}$ .

[0011]

For example, JP 9(1997)-283060 A discloses that lower wirings are formed under an insulating film, a belt-shaped insulating film is then provided so as to intersect with the lower wirings at a right angle, and upper wirings are provided on the belt-shaped insulating film.

[0012]

Therefore, like the plasma display panel, the image forming apparatus using cold cathode electron-emitting elements needs an insulating film, and the insulating film needs to have electrical insulating properties and exhibit a shielding effect as a protective film. Typically, such an insulating film is formed by a method such as vacuum evaporation, sputtering, coating, or the like.

[0013]

However, the methods utilizing a vacuum such as vacuum evaporation and sputtering require costly production facilities. Especially in the case of manufacturing FPD, which seeks an increased area as described above, the manufacturing costs become even higher. Therefore, in FPD, reasonable coating methods such as screen printing and die coating commonly are used as a method of forming an insulating film.

[0014]

[Problem to be solved by the invention]

However, when an insulating film is formed by the coating method, voids and/or pin-holes are generated in the resultant insulating film unless characteristics of the paint used for forming the film has been optimized. Thus, according to the coating method, it is difficult to obtain an insulating film producing a desired insulating effect. The voids and/or pin-holes are considered to be generated as a result of incorporation of foreign materials and/or air bubbles. Other than this, the insufficient wettability of the solvent contained in the paint is considered to be the major cause of the generation of the voids and/or pin-holes.

[0015]

If the solvent has a poor wettability to the surface to be coated with the paint, crawling occurs, which accompanies the generation of cavities. Crawling is the phenomenon in which the paint is not spread evenly on the surface so that uncoated portions result. Therefore, the resultant insulating film is formed unevenly and a desired insulating effect thus cannot be obtained. Further, when the surface to be coated with the paint has roughness, the chances of crawling occurring and the generation of cavities increase. Moreover, when the surface to be coated with the paint is formed of two or more materials, e.g., the case where Ag is formed on a glass substrate in a stripe-shape, the occurrence of crawling and the generation of the cavities become more remarkable. As a result, the resultant insulating film is formed still more unevenly so that some portions of the film have a thickness smaller than the other portions of the film. A desired insulating effect thus cannot be obtained.

[0016]

Conventional paints for forming an insulating film generally contain  $\alpha$ -terpineol or butyl carbitol acetate as a solvent. However, these solvents do not have a good wettability to glass and thus causes crawling of the paint, which accompanies the generation of voids and/or pin-holes in the resultant film, separation of the film, etc.

[0017]

Therefore, in conventional paints for forming an insulating film, firing characteristics of the paints have been controlled by adjusting the composition of the inorganic component, especially glass powder, to obtain a desired insulating effect. However, no attempt has been made to control the wettability of the paints by adjusting the composition of the solvent as a dispersion medium necessary to form the paints.

[0018]

Therefore, with the foregoing in mind, it is an object of the present invention to solve the above-described problems in the prior art. More particularly, it is an object of the present invention to provide a paint for forming an insulating film, which has a good wettability to a surface to be coated with the paint and has no voids or pin-holes after being fired.

[0019]

Furthermore, it is also an object of the present invention to provide a PDP in which dielectric layers provided on its front plate are formed using the paint, a PDP in which dielectric layers provided on its back plate are formed using the paint, a PDP in which partition walls provided on its back plate are formed using the paint, and a method of manufacturing these PDPs.

[0020]

[Means for solving problem]

In order to achieve the above object, the present invention provides, as a first invention (corresponding to claim 1), a paint for forming an insulating film including: an inorganic component comprising inorganic fine particles, and an organic component comprising at least a resin for binding the inorganic fine particles and a solvent in which the resin is dissolved, wherein the solvent forms a contact angle of less than  $5^{\circ}$  with an inorganic material.

[0021]

Furthermore, the present invention provides, as a second invention (corresponding to claim 2), the paint for forming an insulating film according to the present invention as described above, wherein the inorganic material is at least one selected from glass compounds, ceramic compounds, and metal compounds.

[0022]

Furthermore, the present invention provides, as a third invention (corresponding to claim 3), the paint for forming an insulating film according to the present invention as described above, wherein the solvent contains 50 wt. % or more of at least one solvent selected from diethyl carbitol and carbitol acetate.

[0023]

Furthermore, the present invention provides, as a fourth invention (corresponding to claim 4), the paint for forming an insulating film according to the present invention as described above, wherein the paint is used for forming an insulating film used in a plasma display panel, a plasma address liquid crystal display, or an image forming apparatus using an electron-emitting element.

[0024]

Furthermore, the present invention provides, as a fifth invention (corresponding to claim 5), a method of manufacturing a back plate of a plasma display panel including: coating the above-described paint for forming an insulating film according to the present invention onto a back plate of a plasma display panel, the back plate being provided with address electrodes, and firing the paint to form an address electrode protective film.  
[0025]

Furthermore, the present invention provides, as a sixth invention (corresponding to claim 6), the method according to the present invention as described above, wherein ultraviolet cleaning is performed before forming the address electrode protective film.  
[0026]

Furthermore, the present invention provides, as a seventh invention (corresponding to claim 7), a back plate of a plasma display panel having an address electrode protective film formed by the above-described method of manufacturing a back plate of a plasma display panel according to the present invention.  
[0027]

Furthermore, the present invention provides, as an eighth invention (corresponding to claim 8), a method of manufacturing a back plate of a plasma display panel including: coating the above-described paint for forming an insulating film according to the present invention onto a back plate of a plasma display panel, and firing the paint to form a partition wall.  
[0028]

Furthermore, the present invention provides, as a ninth invention (corresponding to claim 9), the method according to the present invention as described above, wherein ultraviolet cleaning is performed before forming the address electrode protective film.  
[0029]

Furthermore, the present invention provides, as a tenth invention (corresponding to claim 10), a back plate of a plasma display panel having a partition wall formed by the above-described method of manufacturing a back plate of a plasma display panel according to the present invention.  
[0030]

Furthermore, the present invention provides, as an eleventh

invention (corresponding to claim 11), a method of manufacturing a front plate of a plasma display panel including: coating the above-described paint for forming an insulating film according to the present invention onto a front plate of a plasma display panel, the front plate being provided with display electrodes, and firing the paint to form a dielectric layer.

[0031]

Furthermore, the present invention provides, as a twelfth invention (corresponding to claim 12), the method according to the present invention as described above, wherein ultraviolet cleaning is performed before forming the address electrode protective film.

[0032]

Furthermore, the present invention provides, as a thirteenth invention (corresponding to claim 13), a front plate of a plasma display panel having a partition wall formed by the above-described method of manufacturing a front plate of a plasma display panel according to the present invention.

[0033]

[Mode for carrying out the invention]

Hereinafter, embodiments of the present invention will be described.

[0034]

A paint for forming an insulating film according to the present invention suitably is used for forming an insulating film formed in a plasma display panel, a plasma address liquid crystal display, or an image forming apparatus using electron-emitting elements.

[0035]

In the paint for forming an insulating film according to the present invention, it is necessary that a solvent for dispersing an inorganic component and dissolving a binder resin forms a contact angle of less than  $5^\circ$  with an inorganic material.

[0036]

The paint for forming an insulating film according to the present invention is coated onto a desired portion so that the resultant paint film has a desired thickness. The paint film is processed or patterned, if necessary, and then fired so as to complete the thermal decomposition of the organic component (i.e., remove the binder). The paint film thus turns to

an insulating film. In the case where the paint for forming an insulating film according to the present invention has a poor wettability to the surface to be coated with the paint, crawling occurs between the paint and the surface coated with the paint, which leads to the generation of voids and/or pin-holes in the paint film and to the separation of the paint film due to the insufficient adhesion between the paint and the surface. Therefore, it is important that the paint has a good wettability to the surface to be coated with the paint. Since the wettability of the paint to the surface to be coated with the paint primarily is influenced by the wettability of the solvent to the surface, it is necessary that the solvent has a good wettability to the material of the surface to be coated with the paint, and it is preferable that the solvent forms a contact angle of less than  $5^\circ$  with the inorganic material. [0037]

Also, the paint for forming an insulating film according to the present invention preferably is used for forming partition walls provided on a back plate of a plasma display panel. Typically, the partition walls are formed on a back dielectric layer serving as an address-electrode protective film, and the back dielectric layer is a glass thin film or a ceramic thin film. Thus, it is necessary that the paint for forming an insulating film according to the present invention has a good wettability to glass and ceramic. In particular, it is preferable that the solvent contained in the paint forms a contact angle of less than  $5^\circ$  with glass and ceramic. [0038]

The method of forming the partition walls by the patterning may be as follows. For example, patterning by screen printing may be performed repeatedly, or a pattern may be etched by sandblasting after the paint has been coated on the entire surface of the back dielectric layer by screen printing or die coating. When the paint has a poor wettability to the back dielectric layer, which is a surface to be coated with the paint, there arise the problems such that the resultant partition walls collapse due to the voids generated inside the partition walls and the paint film is etched unevenly by sandblasting. [0039]

Further, the paint for forming an insulating film according to the present invention preferably is used for forming a dielectric layer and a

protective film used in a plasma display panel or a plasma address liquid crystal display; and an interlayer insulating film for insulation of element electrodes and upper and lower wirings used in an image forming apparatus using electron-emitting elements. These layers and film are formed on glass substrates such as lead glass and a blue glass plate and on metal electrodes formed on the glass substrates. Thus, it is necessary that the paint for forming an insulating film according to the present invention has a good wettability to both a glass compound and a metal compound. In particular, it is preferable that the solvent contained in the paint forms a contact angle of less than  $5^{\circ}$  with a glass compound and a metal compound.

[0040]

The solvent used in the paint for forming an insulating film according to the present invention preferably contains 50 wt. % or more of at least one solvent selected from diethyl carbitol and carbitol acetate.

[0041]

When a solvent contains two or more organic solvents, the wettability of the solvent strongly is affected by the proportion of the organic solvents. For example, when a solvent with a good wettability to the glass substrate and a solvent with a poor wettability to the same are mixed with each other, the wettability of the resultant mixed solvent increases in keeping with the proportion of the solvent with a good wettability. The above-mentioned two organic solvents both form a contact angle of less than  $5^{\circ}$  with glass, ceramic, and a metal compound, and thus have an excellent wettability to the above-mentioned inorganic material. Thus, these solvents have a good wettability not only to the glass substrate but also to a composite substrate such as a glass substrate including metal electrodes and the like formed thereon. Therefore, it is preferable that the paint for forming an insulating film according to the present invention contains 50 wt. % or more of at least one solvent selected from diethyl carbitol and carbitol acetate as described above to improve the wettability of the paint to the surface to be coated with the paint and prevent the generation of voids and/or pin-holes.

[0042]

Examples of the solvent other than the above-mentioned two organic solvents include terpenes such as  $\alpha$ -,  $\beta$ -, and  $\gamma$ -terpineols; ethylene glycol

monoalkyl ethers; ethylene glycol dialkyl ethers; diethylene glycol monoalkyl ethers; diethylene glycol dialkyl ethers; ethylene glycol monoalkyl ether acetates; ethylene glycol dialkyl ether acetates; diethylene glycol monoalkyl ether acetates; diethylene glycol dialkyl ether acetates; propylene glycol monoalkyl ethers; propylene glycol dialkyl ethers; propylene glycol monoalkyl ether acetates; propylene glycol dialkyl ether acetates; and alcohols such as methanol, ethanol, isopropanol, and 1-butanol. These solvents may be used alone or in combination of two or more types.

[0043]

Furthermore, examples of the binder resin include cellulosic resins such as nitrocellulose, ethyl cellulose, and hydroxyethyl cellulose; acrylic resins such as polybutyl acrylate and polymethacrylate and copolymers thereof; polyvinyl alcohol; and polyvinyl butyral. In general, in the paint for forming an insulating film prepared, the binder resins may be used alone or in combination of two or more types.

[0044]

As a compound contained in the inorganic fine particles as an inorganic component contained in the paint for forming an insulating film according to the present invention,  $\text{SiO}_2$ ,  $\text{ZnO}$ ,  $\text{B}_2\text{O}_3$ ,  $\text{PbO}$ ,  $\text{Bi}_2\text{O}_3$ ,  $\text{BaO}$ ,  $\text{P}_2\text{O}_5$ , and  $\text{CaO}$  are preferable. Low melting point glass generally used as an insulating film is formed using glass powder containing at least two of these oxides. In particular, glass powder containing  $\text{PbO}$  as a main component preferably is used because of its ease of control, e.g., ease of softening-point adjustment.

[0045]

The paint for forming an insulating film according to the present invention may further contain as a filler at least one selected from ceramic such as titania, alumina, barium titanate, and zirconia; and high melting point glass. These fillers reduce the rate of shrinkage during firing upon reducing the thermal expansion coefficient, thereby reducing the stress applied onto the substrate. In particular, when the paint contains a white filler, a plasma display panel that can display an image having a high luminance can be obtained because the white filler improves the reflection of display light.



[0046]

The above-mentioned glass compounds are in powder forms because they generally are synthesized by quenching and pulverizing molten glass compounds. Accordingly, the paint can be prepared by mixing at least the powdered glass; an organic solvent for dispersing the powdered glass; and a resin as a binder for uniformly dispersing the powdered glass in the organic solvent as well as preventing the paint film obtained after the paint has been coated and dried from losing its shape.

[0047]

By firing the thus prepared paint after it has been coated and dried, a desired insulating film is obtained. The organic solvent as a dispersion medium is volatilized during drying, the resin as a binder is volatilized during firing, and only the glass component is left. It is to be noted here that the above-mentioned glass compounds contain oxides of respective elements and thus there is no chance that the chemical structure of the glass compounds might change due to the reaction with a resin as a binder and an organic solvent as a dispersion medium. That is, the organic solvent as a dispersion medium and the resin as a binder are necessary to enable the use of inexpensive coating-type forming methods when forming an insulating film using glass powder. Therefore, compounds that form glass when fired preferably are used as an inorganic component contained in the paint for forming an insulating film according to the present invention. The same applies with regard to ceramic fine particles.

[0048]

Further, the paint for forming an insulating film according to the present invention may contain a dispersing agent, a plasticizer, a viscosity modifier, an oligomer, a polymer, an ultraviolet absorber, a photosensitive monomer, a photoinitiator, a sensitizer, etc., if necessary. Examples of the dispersing agent include dibutylphthalate, dioctyl phthalate, polyethylene glycol, and glycerin. Examples of the viscosity modifier include thixotropic agents such as an aerosil.

[0049]

The paint for forming an insulating film according to the present invention can be prepared as follows, for example: various components such as inorganic particles, a binder resin, a solvent, a dispersing agent, a

plasticizer, an oligomer, a polymer, an ultraviolet absorber, a photosensitive monomer, a photoinitiator, a sensitizer, and other additives and solvent are mixed with each other to give a mixture having a desired composition, and these component are dispersed uniformly by a dispersing machine such as a three-roller mill, a ball mill, and a sand mill.

[0050]

The paint for forming an insulating film according to the present invention suitably is used for forming an insulating film used in a plasma display panel, a plasma address liquid crystal display, or an image forming apparatus using electron-emitting elements.

[0051]

Hereinafter, a method of forming a back plate of a plasma display panel of the invention with the use of a paint for forming an insulating film of the invention will be explained.

[0052]

A back plate of a plasma display panel typically includes a back glass substrate 2 on which address electrodes 5, a back dielectric layer 8 as a protective film, partition walls 9, and phosphors 6 are formed.

[0053]

Accordingly, when manufacturing the back plate, the address electrodes 5 are formed on the back glass substrate 2, in the first place. As an electrode material, a metal compound such as Ag, Cr-Cu-Cr, or the like preferably is used on account of the resistance, adherence to the glass substrate, etc. Further, when the electrode material contains a small amount of glass component, address electrodes having excellent adherence to the glass substrate can be obtained.

[0054]

Next, on the back glass substrate 2 with the address electrodes 5 formed thereon, a back dielectric layer 8 as an address electrode protective film is formed using a paint for forming an insulating film according to the preset invention.

[0055]

The paint is coated onto the glass substrate 2 to form a dielectric paint film having a thickness of 5 to 30  $\mu\text{m}$  so that the thickness of the film becomes 2 to 10  $\mu\text{m}$  after firing. Then, by firing the dielectric paint film,

the back dielectric layer 8 as an address-electrode protective film is obtained. The coating of the paint can be performed by the methods generally utilized, e.g., screen printing, bar coating, roll coating, die coating, and doctor blade. An atmosphere in which the firing is performed and a firing temperature are determined depending on the characteristics of the paint and the substrate. However, it is preferable to perform the firing in air or a nitrogen atmosphere. As a furnace, a batch-type or belt-type furnace or a walking-beam-type continuous furnace can be used.

[0056]

Further, as described above, in the case where the dielectric paint film is formed by coating the paint for forming an insulating film, ultraviolet cleaning preferably is performed before coating the paint onto the substrate.

[0057]

Ultraviolet cleaning is a method of removing organic dirt on the glass substrate and the electrodes. The organic compounds composing the dirt are gasified upon being decomposed and oxidized by the energy of ultraviolet rays and  $O_3$  generated by the ultraviolet rays until they finally become  $CO_2$  and  $H_2O$ . Since the organic dirt on the glass substrate and the electrodes is removed by ultraviolet cleaning, the wettability of the paint to the glass substrate and the electrodes is made uniform on the substrate, thereby suppressing crawling due to the non-uniformity of the wettability on the surface of the substrate.

[0058]

An organic component contained in the paint for forming an insulating film may be photosensitive, and the back dielectric layer 8 can be obtained by forming a dielectric paint film by a method such as an entire exposure process and firing it.

[0059]

Next, on the back plate of a plasma display panel with the back dielectric layer 8 formed thereon, the partition walls 9 are formed using the paint for forming an insulating film according to the present invention.

[0060]

The paint is coated onto the glass substrate 2 to form a dielectric paint film having a thickness of 300 to 600  $\mu m$  so that the thickness of the film becomes 100 to 200  $\mu m$  after firing. A patterned protective film is

attached to the dielectric paint film and a portion that is not protected by the protective film is etched by sandblasting. Then, by firing the dielectric paint film after the protective film is removed, the partition walls 9 are obtained.

[0061]

When forming the partition walls 9, the coating and the firing of the paint can be performed by the methods generally utilized, as in the case of forming the back dielectric layer 8.

[0062]

Also, as in the case of forming the back dielectric layer 8, ultraviolet cleaning preferably is performed before coating the paint onto the substrate. By performing the ultraviolet cleaning, the wettability of the paint to the back dielectric layer 8 is made uniform on the substrate, thereby suppressing the crawling due to the non-uniformity of the wettability on the surface of the substrate.

[0063]

An organic component contained in a paint for forming an insulating film may be photosensitive, and the partition walls 9 can be obtained by forming a dielectric paint film by photolithography such as pattern exposure and firing it. The photolithography is preferable because it can provide high-definition partition walls 9 with a high aspect ratio.

[0064]

Further, the back plate of the plasma display panel can be manufactured by firing the back dielectric layer 8 and the partition walls 9 simultaneously, instead of firing them separately as described above.

[0065]

As specifically described above, by the method of manufacturing a back plate of a plasma display panel according to the present invention, the back dielectric layer 8 and the partition walls 9 can be manufactured with a high yield.

[0066]

Further, the back plate of a plasma display panel obtained by the manufacturing method of the invention can be used suitably because it includes an insulating film having few voids and/or pin-holes and thus produces an excellent insulating effect.

[0067]

In the following, a method of forming a front plate of a plasma display panel of the invention with the use of a paint for forming an insulating film of the invention will be explained.

[0068]

As described above, a front plate of a plasma display panel typically includes a front glass substrate 1; transparent electrodes 3 formed on the glass substrate 1; two display electrodes 4 formed on each transparent electrode 3; a front dielectric layer 7 covering them; and an MgO film 10 as a protective film.

[0069]

The front dielectric layer 7 is provided for preventing leakage from occurring between the respective display electrodes 4 and between the display electrodes 4 and the address electrodes 5. Thus, it is necessary that the front dielectric layer 7 produce a desired insulating effect. However, unlike the partition walls 9 provided on the back glass substrate 2, the front dielectric layer 7 need not be patterned. Conversely, the front dielectric layer (7) should be a flat thin film having a high transparency to suppress irregularity of the display. Accordingly, the front dielectric layer 7 can be obtained by coating the paint for forming an insulating film by printing, and then drying and firing the paint.

[0070]

First, the transparent electrodes 3, which generally are formed of ITO, are formed on the front glass substrate 1 by sputtering or the like. Subsequently, the transparent electrodes 3 are patterned by screen printing or photolithography and then fired to form display electrodes 4. As the electrode material, the same material as used for forming the address electrodes 5 can be used.

[0071]

Next, the paint for forming an insulating film according to the present invention is coated onto the front glass substrate 1 to form a dielectric paint film having a thickness of 30 to 150  $\mu\text{m}$  so that the thickness of the film becomes 10 to 50  $\mu\text{m}$  after firing. Then, by firing the dielectric paint film, the front dielectric layer 7 is obtained.

[0072]

The coating and the firing of the paint can be performed by the methods generally utilized, as in the case of forming the back dielectric layer 8 and the partition walls 9.

[0073]

Also, as in the case of forming the back dielectric layer 8 and the partition walls 9, ultraviolet cleaning preferably is performed before coating the paint onto the substrate. By performing the ultraviolet cleaning, the wettability of the paint to the front glass substrate 2 and the transparent electrodes 3 is made uniform on the substrate, thereby suppressing the crawling due to the non-uniformity of the wettability on the surface of the substrate.

[0074]

An organic component contained in a paint for forming an insulating film may be photosensitive, and the front dielectric layer 7 can be obtained by forming a dielectric paint film by photolithography such as pattern exposure and firing it.

[0075]

The front plate of a plasma display panel obtained by the manufacturing method of the invention can be used suitably because it includes an insulating film having few voids and/or pin-holes and thus produces an excellent insulating effect.

[0076]

Hereinafter, the present invention will be explained in further detail with reference to examples. However, it is to be noted that the present invention is not limited to these examples. In the examples, "%" means "wt. %" unless otherwise stated.

[0077]

[EXAMPLE]

(Examples 1 and 2 and Comparative Examples 1 and 2)

Wettabilities of organic solvents were evaluated by measuring their contact angles with various substrates formed of an inorganic material using a contact angle measuring instrument. As the substrates formed of an inorganic material, there were used a glass substrate (PD-200: Asahi Glass Company, Ltd.), which is generally used in PDPs, and glass substrates on the entire surfaces of which ITO, Ag, Cu, and Cr are evaporated,

respectively. As the organic solvents, organic solvents shown below were examined.

[0078]

Example 1: diethyl carbitol

(diethylene glycol dithyl ether)

Example 5: carbitol acetate

(diethylene glycol monoethyl ether acetate)

Comparative Example 1:  $\alpha$ -terpineol

Comparative Example 2: butyl carbitol acetate

(diethylene glycol mono-n-butyl ether acetate)

Further, ultraviolet (hereinafter, referred to as "UV") cleaning was performed on glass substrates of the same type after electrodes had been formed thereon, and contact angles of the organic solvents with these substrate also were measured.

[0079]

The results of the measurement are shown in Table 1. Table 1 shows an average value of the values obtained by measuring each contact angle for five times. However, in the case where the measured value varied greatly, the range of the variation is shown instead of the average value.

[0080]

[Table 1]

Example No.			Example		Comparative Example	
			1	2	1	2
contact angle	glass substrate	untreated	< 5°	0°– 8°	14.1°	8.1°
		UV-treated	< 5°	< 5°	17.0°	12.8°
	ITO film	untreated	< 5°	0°– 10°	6.2°	< 5°
		UV-treated	< 5°	< 5°	5.9°	< 5°
	Ag sputtered film	untreated	< 5°	0°-10°	< 5°	< 5°
		UV-treated	< 5°	< 5°	< 5°	< 5°
	Cu sputtered film	untreated	< 5°	0°– 9°	< 5°	< 5°
		UV-treated	< 5°	< 5°	< 5°	< 5°
	Cr sputtered film	untreated	< 5°	0°– 10°	< 5°	< 5°
		UV-treated	< 5°	< 5°	< 5°	< 5°
breakdown voltage	Ag electrode	untreated	1.8 kV	1.3 kV	0.6 kV	0.6 kV
		UV-treated	1.9 kV	1.8 kV	0.5 kV	0.6 kV
	Cr-Cu-Cr electrode	untreated	1.6 kV	1.2 kV	0.4 kV	0.6 kV
		UV-treated	1.7 kV	1.8 kV	0.6 kV	0.6 kV
effect of protecting address electrode		untreated	○	○	×	×
		UV-treated	○	○	×	×
effect as partition walls		untreated	○	△	×	×
		UV-treated	○	○	×	×

[0081]

As shown in Table 1, although the solvents used in Comparative Examples 1 and 2, which are the solvents used in a conventional paint for forming an insulating film, had a good wettability to the metal compounds like Ag, Cu, and Cu,  $\alpha$ -terpineol used in Comparative Example 1 had a somewhat poor wettability to the ceramic like ITO and still poorer wettability to the glass substrate. The same results were obtained with respect to the UV-treated substrates.

[0082]

On the other hand, the solvent used in Example 1 had an excellent wettability to the glass substrate, metal compounds, and ceramic. The



same results were obtained with respect to the UV-treated substrates.

[0083]

The contact angles of the solvent used in Example 2 with the untreated substrate slightly varied depending on where the measurements were made on the substrates. However, the solvent had a good wettability to any portion of the UV-treated substrate.

[0084]

Using the solvents that contain 100% of the organic solvents used in the above-mentioned respective examples and comparative examples, paints for forming an insulating film were prepared in the following manner.

[0085]

As glass powder, a lead oxide glass frit (composition:  $\text{PbO} \cdot \text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{SiO}_2$ ) was used.

[0086]

200 g of vehicle (the solvent containing a resin dissolved therein) containing 10% of ethyl cellulose and 300 g of the lead oxide glass frit were pre-mixed with each other, and then mixed with the three-roller mill to prepare a paint for forming an insulating film.

[0087]

The insulation performance (breakdown voltage) of dielectric layers obtained by coating the respective paints for forming an insulating film was determined in the following manner.

[0088]

A firing-type Ag paste was printed onto a glass substrate (PD-200) and then fired at 590°C to form lower electrodes. Then, the paint for forming an insulating film according to the present invention was printed over the glass substrate so that ends of the lower electrodes were exposed. The paint was then fired at 590°C. The printing conditions were adjusted so that the thickness of the dielectric layer would be 30  $\mu\text{m}$  after firing. Subsequently, a thermosetting-type Ag paste further was coated in such a manner that the Ag paste came within the area of the lower electrodes. The Ag paste thus coated was heated at 150°C to form upper electrodes. The breakdown voltage was measured using a breakdown voltage measuring instrument (Kikusui Electronics Corp.), which was connected to the dielectric layer via the contacts provided in the ends of each one of the

lower electrodes and upper electrodes, respectively, so as to oppose each other. The moment when the leakage current of 0.5 mA occurred was regarded as dielectric breakdown, and the voltage at this time was measured as a breakdown voltage. The breakdown voltage of the dielectric layer formed on Cr-Cu-Cr electrodes also was measured in the same manner.

[0089]

As is apparent from Table 1, the dielectric layers formed using the paint of Example 1 had no voids or pin-holes and had excellent voltage endurance characteristics.

[0090]

The dielectric layer formed using the paint of Example 2 had no voids or pin-holes and had voltage endurance characteristics sufficient for practical use even when formed on the untreated substrates. The dielectric layer had further improved in voltage endurance characteristics when UV cleaning had been performed on the substrates.

[0091]

On the other hand, the dielectric layers formed using the paints of Comparative Examples 1 and 2 had voids and/or pin-holes, and had voltage endurance characteristics somewhat inferior to those of the dielectric layer of Examples 1 and 2.

[0092]

Next, with respect to the insulating film formed using the paints, effects as address electrode protective films were evaluated. A firing-type Ag paste was printed onto a glass substrate (PD-200) and then fired at 590°C to form lower electrodes. Then, the paint for forming an insulating film according to the present invention was printed on the entire surface of the glass substrate so that the thickness of the paint film would be 3  $\mu\text{m}$  after firing. The paint film then was fired at 590°C. The insulating film thus obtained was formed by coating the paint once. The results are shown in Table 1.

[0093]

As is apparent from Table 1, the address electrode protective films formed using the paints of Examples 1 and 2 had no defects such as voids or pin-holes and had a sufficient effect as a protective film.

[0094]

On the other hand, the address electrode protective films formed using the paints of Comparative Examples 1 and 2 had voids and/or pin-holes, and had an insufficient effect as a protective film.

[0095]

Furthermore, effects as partition walls also were evaluated. The paint for forming an insulating film according to the present invention was printed onto a glass substrate (PD-200) so that the thickness of the paint film would be 200  $\mu\text{m}$  after firing, followed by drying. The paint film was then covered with a patterned protective film, and the pattern of partition walls was etched by sandblasting. After the protective film has been removed, the glass substrate was fired at 590°C to form partition walls. The results of the evaluation are shown in Table 1.

[0096]

As is apparent from Table 1, the partition walls formed using the paints of Example 1 had no defects such as voids or pin-holes, and a portion of the partition walls was not separated from the glass substrate. The partition walls formed using the paint of Example 2 had no voids or pin-holes, but they were separated from the glass substrate in some cases. However, the occurrence of the separation of the partition walls was suppressed when UV cleaning had been performed on the glass substrate.

[0097]

On the other hand, in the partition walls formed using the paints of Comparative Examples 1 and 2, voids and/or pin-holes were generated, a region where no partition wall was formed was generated, and a portion of the partition walls was separated from the glass substrate.

[0098]

(Examples 3 to 6 and Comparative Examples 3 and 4)

Wettabilities of the mixed solvents obtained by mixing the organic solvents in the ratio shown in Table 2 were evaluated in the same manner as in Examples 1 and 2 and Comparative Examples 1 and 2. In Table 2, DCr denotes diethyl carbitol; CrAc denotes carbitol acetate; and BCA denotes butyl carbitol acetate. Paints for forming an insulating film were prepared and the breakdown voltage, the effect of protecting address electrodes, and the effect as partition walls were evaluated in the same

manner as in Examples 1 and 2 and Comparative Examples 1 and 2. The results are shown in Table 3.

[0099]

[Table 2]

	DCr	CrAc	BCA
Example 3	3		1
Example 4	1		1
Comparative Example 3	1		3
Example 5		3	1
Example 6		1	1
Comparative Example 4		1	3

[0100]

[Table 3]

Example No.			Example				Comparative Example	
			3	4	5	6	3	4
contact angle	glass substrate	untreated	< 5°	< 5°	0°- 7°	0°- 10°	8.4°	11.3°
		UV-treated	< 5°	< 5°	< 5°	< 5°	7.6°	13.2°
	ITO film	untreated	< 5°	< 5°	< 5°	< 5°	< 5°	< 5°
		UV-treated	< 5°	< 5°	< 5°	< 5°	< 5°	< 5°
	Ag sputtered film	untreated	< 5°	< 5°	< 5°	< 5°	< 5°	< 5°
		UV-treated	< 5°	< 5°	< 5°	< 5°	< 5°	< 5°
	Cu sputtered film	untreated	< 5°	< 5°	< 5°	< 5°	< 5°	< 5°
		UV-treated	< 5°	< 5°	< 5°	< 5°	< 5°	< 5°
	Cr sputtered film	untreated	< 5°	< 5°	< 5°	< 5°	< 5°	< 5°
		UV-treated	< 5°	< 5°	< 5°	< 5°	< 5°	< 5°
breakdown voltage	Ag electrode	untreated	1.8 kV	1.7 kV	1.3 kV	1.2 kV	0.8 kV	0.5 kV
		UV-treated	1.8 kV	1.8 kV	1.7 kV	1.8 kV	0.7 kV	0.5 kV
	Cr-Cu-Cr electrode	untreated	1.7 kV	1.7 kV	1.3 kV	1.2 kV	0.7 kV	0.5 kV
		UV-treated	1.7 kV	1.8 kV	1.6 kV	1.6 kV	0.7 kV	0.4 kV
effect of protecting address electrode		untreated	○	○	○	○	×	×
		UV-treated	○	○	○	○	×	×
effect as partition wall		untreated	○	○	△	△	×	×
		UV-treated	○	○	○	○	△	×

[0101]

As is apparent from Table 3, the dielectric layers formed using the paints of Examples 3 and 4 had no voids or pin-holes and had excellent voltage endurance characteristics.

[0102]

The dielectric layers formed using the paint of Examples 5 and 6 had no voids or pin-holes and had voltage endurance characteristics sufficient for practical use even when formed on the untreated substrates. These dielectric layers had further improved in voltage endurance characteristics when UV cleaning had been performed on the substrates.

[0103]

On the other hand, the dielectric layers formed using the paints of Comparative Examples 3 and 4 had voids and/or pin-holes, and had voltage endurance characteristics somewhat inferior to those of the dielectric layers of Examples 3 to 6.

[0104]

Further, regarding the effect of protecting address electrodes, the address electrode protective films formed using the paints of Examples 3 to 6 had no defects such as voids or pin-holes and had a sufficient effect as a protective film, as is apparent from Table 3.

[0105]

On the other hand, the address electrode protective films formed using the paints of Comparative Examples 3 and 4 had voids and/or pin-holes, and had an insufficient effect as a protective film.

[0106]

Further, regarding the effect as partition walls, the partition walls formed using the paints of Examples 3 and 4 had no defects such as voids or pin-holes, and a portion of the partition walls was not separated from the glass substrate, as is apparent from Table 3. Further, the partition walls formed using the paint of Examples 5 and 6 had no voids or pin-holes, but they were separated from the glass substrate in some cases. However, the occurrence of the separation of the partition walls was suppressed when UV cleaning had been performed on the glass substrate.

[0107]

On the other hand, in the partition walls formed using the paints of Comparative Examples 5 and 6, voids and/or pin-holes were generated, a region where no partition wall was formed was generated, and a portion of the partition walls was separated from the glass substrate.

[0108]

[Effects of the invention]

A paint for forming an insulating film according to the present invention includes as a main solvent an organic solvent that has a good wettability to a glass compound (glass substrate), a metal compound (Ag electrode), and a ceramic compound (ITO ceramic film) and forms a contact angle of less than  $5^\circ$  with these inorganic materials, the main solvent being at least 50 wt. % of the whole solvent. Thus, the paint has a good

wettability to a glass substrate, an Ag electrode, and an ITO film and occurrence of the crawling and generation of cavities thus can be prevented. [0109]

In addition, a plasma display panel can be obtained with high yield by forming a dielectric layer on its front glass substrate, or a dielectric layer or partition walls on its back glass substrate using a paint for forming an insulating film according to the present invention.

#### [BRIEF DESCRIPTION OF THE DRAWINGS]

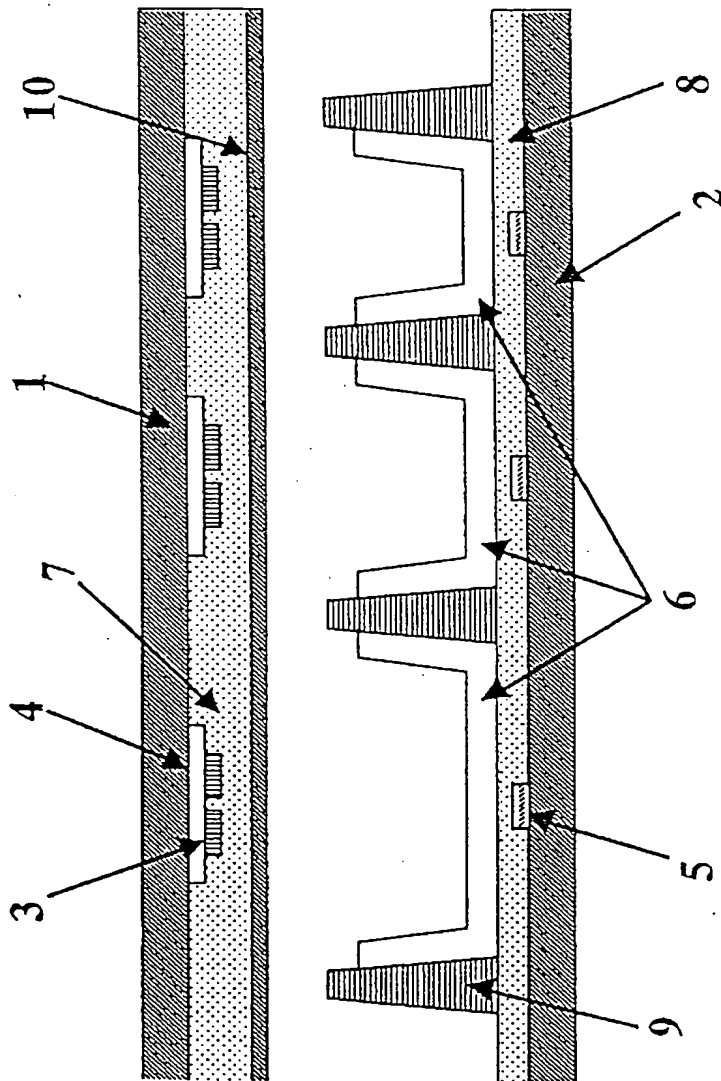
[FIG. 1] FIG. 1 is a view illustrating a structure of a PDP

[Explanation of letters or numerals]

- 1: front glass substrate
- 2: back glass substrate
- 3: display electrode
- 4: transparent electrode
- 5: address electrode
- 6: phosphor
- 7: front dielectric layer
- 8: back dielectric layer
- 9: partition wall
- 10: MgO film

[Document Name] Drawings

[FIG. 1]





[Name of the Document]      ABSTRACT

[Abstract]

[Object]    To provide a paint for forming an insulating film that has a good wettability to a surface to be coated with the paint and has no voids or pin-holes after being fired.

[Means for solving the problem]    The paint for forming an insulating film includes as a main solvent an organic solvent that has a good wettability to a glass substrate, an Ag electrode, and an ITO ceramic film and forms a contact angle of less than  $5^{\circ}$  with these inorganic materials, and the main solvent is at least 50 wt. % of the whole solvent. Accordingly, the paint has a good wettability to a glass substrate, an Ag electrode, and an ITO film and the resultant insulating film thus has no voids or pin-holes.

[Selected Figure]    None